

**THE UNIVERSITY OF CHICAGO**

## MULTI-CHANNEL OPTICAL RECORDING USING VCSEL ARRAYS

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# MULTI-CHANNEL OPTICAL RECORDING USING VCSEL ARRAYS

## 5 CLAIM OF PRIORITY

This application claims the benefit of United States Provisional Application Serial No. 60/142,548, filed July 7, 1999, entitled "Multi-Channel Optical Recording Using VCSEL Arrays" by William S. Oakley.

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## BACKGROUND OF THE INVENTION

### Field of the Invention

The present invention relates to optical recording systems.

### Background Information

Optical based systems use light beams to convey and process information. Light beams provide distinct advantages over electrical signals such as higher bandwidth and faster propagation speed. In optical based systems, a light source, such as a laser, is modulated to convey the desired information. By using digital or analog modulation of light beams, optical based systems can be used in a variety of applications, such as optical signal processing and data storage.

Optical recording systems can provide for faster writing of large amounts of data, especially if multiple light sources are used. However, using multiple light sources can increase the complexity and cost of an optical recording system. Thus, it is desirable to have a relatively simple and inexpensive high speed optical recording system.

## **SUMMARY OF THE INVENTION**

The present invention provides an optical recording system having an array of modulatable light sources. An objective lens is positioned relative to the array of modulatable light sources to allow the objective lens to focus at least one light beam from the array of modulatable light sources on a target medium.

In one embodiment of the present invention, the array of modulatable light sources includes an array of Vertical Cavity Surface Emitting Lasers (VCSEL), where each VCSEL of the VCSEL array is capable of writing a separate track on the target medium.

In another embodiment of the present invention, the array of modulatable light sources includes at least one line of modulatable light sources positioned at an angle relative to a direction of movement of said target medium. Each modulatable light source of the line of modulatable light sources is associated with a separate path on the target medium.

Additional features and benefits of the present invention will become apparent upon review of the following description.

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**Figure 2A** illustrates a side perspective view of a VCSEL array embedded in a

**Figure 2B** illustrates a top view of the VCSEL array shown in Figure 2A.

**Figure 2C** illustrates a top view of a VCSEL array embedded in a substrate at an

**Figure 3A** illustrates generally a diagram of an embodiment of an optical

**Figure 3B** illustrates generally a diagram of another embodiment of an optical

## DETAILED DESCRIPTION

The following description provides embodiments of the present invention.

However, it will be appreciated that other embodiments of the present invention will

5 become apparent to those of ordinary skill in the art upon examination of this description. Thus, the present description and accompanying drawings are for purposes of illustration and are not to be used to construe the invention in a restrictive manner.

10 Multi-beam optical signal or data recording onto a target medium, such as tape or disc media, may be implemented in accordance with one embodiment of the present invention by use of an array of light sources, such as Vertical Cavity Surface Emitting Lasers (VCSEL), in an orientation as shown in **Figure 1**. A VCSEL is a semiconductor laser diode that emits light vertically from the surface of a substrate, such as a semiconductor wafer. VCSELs are commonly known and can be fabricated using standard microelectronic fabrication techniques. The two dimensional array of regularly spaced light sources 100 is oriented at a slight angle  $\theta$  to the direction of motion 130 of the target medium as shown in **Figure 1** such that closely spaced tracks can be written on the target medium. It should be noted that light sources 100 are shown in a top-down view. Adjacent light sources 100 are spaced along a row or line by a center-to-center distance 110. Because each line of light sources 100 is positioned at an angle  $\theta$  to the direction of motion 130 of the target medium, each light source 100 can write a separate, non-overlapping track on the target medium. Recorded data patterns may be achieved on each individual track by modulating each light source 100 independently.

The vertical spacing 120 between adjacent light sources 100, and hence the written track spacing, may be adjusted by changing tilt angle  $\theta$ . It should be noted that certain tilt angles  $\theta$  may result in overlapping written tracks on the target medium depending on the spacing 110 between adjacent light sources 100. Although **Figure 1** illustrates 16 light sources in a 2X8 array, it is appreciated that any number of light sources in many different array configurations may be implemented within the scope of the present invention.

In one embodiment of the present invention, light sources 100 have a spacing 110 of approximately 240 microns on the substrate, which may be reduced by, for example, approximately 30X by imaging onto the target medium, thereby providing an imaged array with nominal 8 micron spacing on beam centers. A tilt angle  $\theta$  of 7 degrees further reduces the written track spacing to approximately one micron. A spacing 110 of at least 40 microns may be used to prevent interference between light beams emitted by adjacent light sources 100.

**Figures 2A and 2B** illustrate a side perspective view and a top view, respectively, of an array of VCSELs 220 embedded in a substrate 200. Each VCSEL 220 emits a light beam vertically from the surface 210 of substrate 200. Substrate 200 may be a semiconductor wafer of any suitable shape and size. In **Figure 2B**, VCSELs 220 are shown in a non-angled orientation on substrate 200. Thus, to permit each VCSEL 220 to write a separate, non-overlapping track on a target medium, substrate 200 may be rotated to orient the light beams emitted by VCSELs 220 at an appropriate angle to the direction of motion of the target medium.

In **Figure 2C**, VCSELs 250 are embedded in substrate 230 at an angle  $\theta$ .

Specifically, the array of VCSELs 250 features rows or lines of VCSELs 250, and each line is positioned at an angle  $\theta$  to the direction of motion of the target medium. Each VCSEL 250 emits a light beam vertically from the surface 240 of substrate 230.

- 5 Because VCSELs 250 are already oriented at an angle  $\theta$ , it is not necessary to rotate substrate 230 to achieve a desired write pattern. However, it is appreciated that both the VCSEL substrate and the VCSEL array may be positioned at an angle to the direction of motion of the target medium in order achieve a desired write pattern on the target medium.

**Figure 3A** illustrates generally a diagram of an embodiment of an optical recording system using a VCSEL array 302, which may be positioned at an angle as described above with respect to **Figures 1, 2B and 2C**. The VCSEL outputs pass through a collimating lens 304 and are optically polarized after passing through a polarizing beam-splitter 314. Alternatively, the VCSEL outputs may be polarized by the laser emitter design. The polarized light beams then pass through a circularly polarizing element 312, such as a quarter wave plate, coupled to or adjacent polarizing beam-splitter 314. After exiting element 312, the light beams impinge on a target medium 308 via a focusing objective lens 310. Lens 310 is maintained in a desired focal and tracking position by electromechanical servos (not shown) driven by optical  
20 signal feedback via system detectors 306. Element 312 causes the light impinging on target medium 308 to be circularly polarized, and the light reflecting from target medium 308 travels back through element 312 and beam-splitter 314 and is placed in a

polarization state such that it is reflected to detection system 306 rather than traveling back to VCSEL array 302.

A second VCSEL array operating in a continuous mode can provide read-after-write capability. This second array can be on a separate substrate, or on the same substrate as the writing VCSEL array, and may be interspersed with the writing VCSELs.

For example, **Figure 3B** illustrates generally a diagram of an optical recording system using two VCSEL arrays 352 and 358, each of which may be positioned at an angle as described above with respect to **Figures 1, 2B and 2C**. The system may employ one VCSEL array 352 for writing and one VCSEL array 358 for reading. The writing VCSEL array 352 may project light beams having one wavelength, and the reading VCSEL array 358 may project light beams having a slightly different wavelength, but both arrays may have the same array spacing. The writing VCSELs may be modulated individually to form the data patterns and the reading VCSELs may be operated in a continuous mode when reading is required. Both VCSEL arrays 352 and 358 may operate simultaneously in a read-after-write mode.

In the two-array configuration shown in **Figure 3B**, a focusing objective lens 362 is sufficiently achromatic to cover different wavelengths so that both VCSEL arrays 352 and 358 focus in the same plane at a target medium 364 with the same magnification. The light beams of VCSEL arrays 352 and 358 having slightly differing wavelengths but similar polarization states are combined through a dichroic polarizing beam-splitter 372 after passing through collimating lenses 354 and 356, respectively. The light beams of writing VCSEL array 352 pass directly through the dichroic polarizing beam-splitter 372



and those of the reading VCSEL array 358 are reflected from the beam-splitter internal dichroic surface. The combined beams exit the dichroic polarizing beam-splitter 372 with the same polarization state and pass through a second polarizing beam-splitter 370 and circularly polarizing plate 360 to target medium 364 via focusing objective lens 362. Lens 362 is maintained in a desired focal and tracking position by electromechanical servos (not shown) driven by optical signal feedback via system detectors 368. On being reflected from target medium 364 and back through plate 360, the light beams have their polarization rotated 90 degrees so that they are reflected from beam-splitter 370 to detection system 368 rather than traveling back to their sources. A filter 366 is placed in the path of the light beams reflected from beam-splitter 370 to remove unwanted write energy and allow the read beams to pass to detection system 368 where data is read out.

In the foregoing detailed description, the apparatus and method of the present invention have been described with reference to specific exemplary embodiments. However, it will be evident that various modifications and changes may be made without departing from the broader scope and spirit of the present invention. The present specification and figures are accordingly to be regarded as illustrative rather than restrictive.